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<b>(21) International Application Number:</b> PCT/US97/04131 <b>(22) International Filing Date:</b> 5 March 1997 (05.03.97)  <b>(30) Priority Data:</b> 60/012,820 5 March 1996 (05.03.96) US  <b>(60) Parent Application or Grant</b> (63) Related by Continuation US 60/012,820 (CON) Filed on 5 March 1996 (05.03.96)  <b>(71) Applicant (for all designated States except US):</b> MEDINOX, INC. [US/US]; Suite E, 11555 Sorrento Valley Road, San Diego, CA 92121 (US).  <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> LAI, Ching-San [US/US]; 209 Lolita Street, Encinitas, CA 92024 (US).  <b>(74) Agent:</b> REITER, Stephen, E.; Gray, Cary, Ware & Freidenrich, Suite 1600, 4365 Executive Drive, San Diego, CA 92121 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> COMBINATIONAL THERAPEUTIC METHODS EMPLOYING NITRIC OXIDE SCAVENGERS AND COMPOSITIONS USEFUL THEREFOR  <b>(57) Abstract</b> <p>In accordance with the present invention, there are provided combinational therapeutic methods for the <i>in vivo</i> inactivation or inhibition of formation (either directly or indirectly) of species which induce the expression of nitric oxide synthase, as well as reducing nitric oxide levels produced as a result of .NO synthase expression. In contrast to the inhibitory approach described in the prior art (i.e., wherein the function of the enzymes responsible for nitric oxide production is inhibited), the present invention employs a combination of inactivation (or inhibition) and scavenging approach whereby the stimulus of nitric oxide synthase expression is inactivated, or the production thereof is inhibited, and overproduced nitric oxide is bound <i>in vivo</i> to a suitable nitric oxide scavenger. The resulting complexes render the stimulus of nitric oxide synthase expression inactive (or inhibit the production thereof), and nitric oxide harmless. The resulting complexes are eventually excreted in the urine of the host. In another aspect, the present invention relates to reducing elevated nitric oxide levels associated with infectious and/or inflammatory conditions (and the treatment thereof), employing a combinational therapeutic method wherein an agent for the treatment of the infectious and/or inflammatory condition is coadministered along with a dithiocarbamate compound as a scavenger of overproduced nitric oxide. Further in accordance with the present invention, there are provided compositions and formulations useful for carrying out the above-described methods.</p>		

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Combinational Therapeutic Methods Employing Nitric Oxide  
Scavengers and Compositions Useful Therefor

FIELD OF THE INVENTION

The present invention relates to methods for directly or indirectly treating the production of species which induce the expression of nitric oxide synthase in mammals. In a particular aspect, the present invention relates to methods for inactivating such species, or inhibiting the production of such species, while, at the same time, reducing nitric oxide levels, by co-administration of agents which inactivate (or inhibit the production of) such species, along with a dithiocarbamate compound as a scavenger of overproduced nitric oxide. In another aspect, the present invention relates to reducing elevated nitric oxide levels associated with infectious and/or inflammatory conditions (and the treatment thereof), employing a combinational therapeutic method wherein an agent for the treatment of the infectious and/or inflammatory condition is co-administered along with a dithiocarbamate compound as a scavenger of overproduced nitric oxide. In a further aspect, the present invention relates to compositions and formulations useful in the methods disclosed herein.

BACKGROUND OF THE INVENTION

In 1987, nitric oxide ( $\cdot\text{NO}$ ), a gaseous free-radical, was discovered in humans (see, for example, Ignarro et al., in Proc. Natl. Acad. Sci., USA 84:9265-69 (1987) and Palmer et al., in Nature 327:524-26 (1987)). As an indication of the significance of this discovery for the understanding of human physiology and pathophysiology, Science magazine selected nitric oxide as the molecule of the year in 1992.

Nitric oxide is formed from the terminal guanidino nitrogen atom of L-arginine by nitric oxide synthase (NOS; see, for example, Rodeberg et al., in Am. J. Surg. 170:292-303 (1995), and Bredt and Snyder in Ann. Rev. Biochem. 63:175-95 (1994)). Two major forms of nitric oxide synthase, constitutive and inducible enzymes, have been identified.

Under physiological conditions, a low output of ·NO is produced by the constitutive, calcium-dependent NOS isoform (cNOS) present in numerous cells, including endothelium and neurons. This low level of nitric oxide is involved in a variety of regulatory processes, e.g., blood vessel homeostasis, neuronal communication and immune system function. On the other hand, under pathophysiological conditions, a high output of ·NO is produced by the inducible, calcium-independent NOS isoform (iNOS) which is expressed in numerous cell types, including endothelial cells, smooth muscle cells and macrophages. These high levels of nitric oxide have been shown to be the etiology of endotoxin shock. This high output of ·NO further contributes to inflammation-related tissue damage, neuronal pathology, N-nitrosamine-induced carcinogenesis and mutations in human cells and bacteria via deamination reaction with DNA. Nitric oxide can therefore be seen to be a mixed blessing, being very desirable when present in small amounts, while potentially being highly detrimental when produced in excessive quantities.

Nitric oxide is a potent vasodilator (see, for example, Palmer in Arch. Surg. 128:396-401 (1993) and Radomski & Moncada in Thromb. Haemos. 70:36-41 (1993)). For example, in blood, ·NO produced by the endothelium diffuses isotropically in all directions into adjacent tissues. As ·NO diffuses into the vascular smooth muscle, it binds to guanylate cyclase enzyme, which catalyzes the production of cGMP, inducing vasodilation (see, for example, Ignarro,

L.J., Ann. Rev. Toxicol. 30:535-560 (1990); Moncada, S., Acta Physiol. Scand. 145:201-227 (1992); and Lowenstein and Snyder, Cell 70:705-707 (1992)). The overproduction of nitric oxide causes an extreme drop in blood pressure, resulting in insufficient tissue perfusion and organ failure, syndromes that are associated with many diseases and/or conditions (e.g., septic shock, overexpression of cytokines, allograft rejection, and the like). The overproduction of nitric oxide is triggered by a number of stimuli, such as, the overproduction of inflammatory cytokines (e.g., tumor necrosis factor (TNF), interleukin-1 (IL-1), interferons, endotoxin, and the like). Additionally, the overproduction of NO has been discovered to be one of the major side-effects of cytokine therapy (see, for example, Miles et al., in Eur. J. Clin. Invest. 24:287-290 (1994) and Hibbs et al., in J. Clin. Invest. 89:867-877 (1992)). Thus, abnormally elevated nitric oxide levels have been linked to many inflammatory and infectious diseases.

Inflammatory cytokines (e.g., TNF, interleukins or interferons) and infectious agents (e.g., endotoxin) induce nitric oxide overproduction by inducing transcription of the inducible nitric oxide synthase gene, leading to the production of inducible nitric oxide synthase, which in turn results in the overproduction of nitric oxide. The production of nitric oxide by the above-described pathway can be disrupted in a variety of ways. Thus, for example, there have been attempts to develop monoclonal antibodies (e.g., anti-endotoxin antibodies, anti-cytokine antibodies, anti-cytokine receptor antibodies, and the like) in efforts to block the NO production pathway at the transcriptional level. Unfortunately, however, such efforts have met with very limited success (see, for example, Glauser et al., in Clin. Infect. Dis. 18:S205-16 (1994) and St. John & Dorinsky, in Chest 103:932-943 (1993)). At least one reason for the

relative lack of success in the art is the fact that the production of inflammatory cytokines is short-lived (see, for example, Wange & Steinsham in Eur. J. Haematol. 50:243-249 (1993)), while overproduction of nitric oxide  
5 lasts several days, causing systemic hypotension, insufficient tissue perfusion and organ failure.

Thus, for example, during endotoxemia, TNF production peaks at about 1-2 hours. Therefore, in order to be effective, anti-TNF antibodies would have to be  
10 administered at an early stage after infection. Indeed, in many clinical settings, patients are likely to already have been infected with bacteria prior to being admitted. Accordingly, such therapeutic methods have met with only limited success.

15 Currently, many pharmaceutical companies have turned their attention to the design and development of substrate or product analogue inhibitors of the enzyme, NOS, in efforts to treat the overproduction of NO. However, recent data show that the inhibition of NOS is  
20 detrimental to subjects. For example, rodent studies show that inhibition of the production of nitric oxide causes intrauterine growth retardation and hind-limb disruptions in rats (see, for example, Diket et al., in Am. J. Obstet. Gynecol. 171:1243-1250 (1994)). Furthermore, the  
25 inhibition of nitric oxide synthesis during endotoxemia has also been shown to be detrimental (see, for example, Minnard et al., in Arch. Surg. 129:142-148 (1994); Luss et al., in Biochem. Biophys. Res. Commun. 204:635-640 (1994); and Hargrecht et al., in J. Leuk. Biol. 52:390-394 (1992)).  
30 Similar results have been reported in larger animal studies, such as dogs and swine (see, for example, Statman et al., in J. Surg. Res. 57:93-98 (1994); Mitaka et al., Am. J. Physiol. 268:H2017-H2023 (1994); Robertson, et al., Arch. Surg. 129:149-156 (1994); and Henderson et al., Arch.  
35 Surg. 129:1271-1275 (1994)).

Since a variety of stimuli induce expression of nitric oxide synthase, which, in turn, leads to nitric oxide overproduction (with its attendant detrimental effects), there is a need in the art to effectively treat both the initial stimulus of nitric oxide synthase expression, and the resulting overproduction of nitric oxide, as well as overproduction of nitric oxide which may be induced (directly or indirectly) by therapeutic agents employed for the treatment of a wide variety of infectious and/or inflammatory conditions.

#### BRIEF DESCRIPTION OF THE INVENTION

In accordance with one aspect of the present invention, combinational therapeutic methods have been developed for the in vivo inactivation or inhibition of formation (either directly or indirectly) of species which induce the expression of inducible nitric oxide synthase, as well as reducing nitric oxide levels produced as a result of NO synthase expression. In another aspect, combinational therapeutic methods have been developed which can be employed, for example, for the treatment of infectious and/or inflammatory conditions. Thus, the effectiveness of many therapeutic agents used for the treatment of infectious and/or inflammatory conditions can be enhanced by co-administration thereof in combination with dithiocarbamate-containing nitric oxide scavenger(s).

In contrast to the inhibitory approach described in the prior art to address the problem of nitric oxide overproduction (see, for example, Aisaka et al., Biochem. Biophys. Res. Commun. **60**:881-886 (1989); Rees, et al., Proc. Natl. Acad. Sci. USA **86**:3375-3379, (1989)); Henderson et al., in Arch. Surg. **129**:1271-1275 (1994); Hambrecht et al., in J. Leuk. Biol. **52**:390-394 (1992); Luss et al., in Biochem. and Biophys. Res. Comm. **204**:635-640 (1994); Robertson et al., in Arch. Surg. **129**:149-156 (1994);

Statman et al., in J. Surg. Res. 57:93-98 (1994); and Minnard et al., in Arch. Surg. 129:142-148 (1994)), in one aspect, the present invention employs a combination of inactivation (and/or inhibition) and scavenging approach  
5 whereby the stimulus of nitric oxide synthase expression is inactivated and/or expression thereof is inhibited, and overproduced nitric oxide is bound in vivo to a suitable nitric oxide scavenger. The resulting complexes render the stimulus of nitric oxide synthase expression inactive (or  
10 inhibit the production thereof), while also rendering the resulting nitric oxide harmless. The resulting complexes are eventually excreted in the urine of the host.

In another aspect, a suitable nitric oxide scavenger is co-administered along with a therapeutic agent  
15 which may promote nitric oxide formation, thereby providing a protective affect against the otherwise detrimental effects of nitric oxide overproduction.

Further in accordance with the present invention, there have been developed compositions and formulations  
20 useful for carrying out the above-described methods.

Numerous stimuli for  $\cdot\text{NO}$  synthase are known in the art. Co-administration of agents which inactivate the stimulus of  $\cdot\text{NO}$  synthase expression (or inhibit the production thereof), in combination with nitric oxide  
25 scavengers as described herein, provides a more effective means to treat a variety of indications than has previously been described in the art.

An exemplary nitric oxide scavenger contemplated for use in the practice of the present invention is a  
30 dithiocarbamate-ferrous iron complex. This complex binds to  $\cdot\text{NO}$ , forming a stable, water-soluble dithiocarbamate-iron- $\cdot\text{NO}$  complex having a characteristic three-line spectrum (indicative of a mononitrosyl-Fe complex) which can readily



be detected at ambient temperatures by electron paramagnetic resonance (EPR) spectroscopy (See Komarov et al., in Biochem. Biophys. Res. Commun. 195:1191-1198 (1993); and Lai and Komarov, FEBS Lett., 345:120-124, (1994)). This method of detecting  $\cdot\text{NO}$  in body fluids in real time has recently been described by Lai in U.S. Patent No. 5,358,703, incorporated by reference herein in its entirety.

The present invention relates to combinational therapeutic methods for treating the production of species which induce the expression of nitric oxide synthase in mammals. Thus, a dual attack is mounted against a variety of stimuli which lead to the production of dangerously high in vivo levels of  $\cdot\text{NO}$ . Combinations of agents contemplated for use in the practice of the present invention (i.e., agents capable of inactivating species which induce expression of inducible nitric oxide, or agents which inhibit the production of such species, or therapeutically useful agents which also induce nitric oxide production, and dithiocarbamate-containing nitric oxide scavengers) are administered to a host in need of such treatment. The agent capable of inactivating (or inhibiting the production of) species which induce expression of inducible nitric oxide and  $\cdot\text{NO}$  scavengers interact with the stimulus or stimuli of nitric oxide synthase expression and in vivo produced  $\cdot\text{NO}$ , respectively, forming a complex between said species and said agent, as well as a stable dithiocarbamate-metal- $\text{NO}$  complex. Whereas free  $\cdot\text{NO}$  is a potent vasodilator,  $\cdot\text{NO}$  chelated with dithiocarbamate-iron complexes is not. The  $\text{NO}$ -containing complex is then filtered through the kidneys, concentrated in the urine, and eventually excreted by the subject, thereby reducing in vivo  $\cdot\text{NO}$  levels.

In another aspect, the present invention relates to reducing elevated nitric oxide levels associated with

infectious and/or inflammatory conditions (and the treatment thereof). In accordance with this aspect of the invention, a combinational therapeutic method is employed wherein an agent for the treatment of an infectious and/or inflammatory condition is co-administered along with a dithiocarbamate compound as a scavenger of overproduced nitric oxide.

#### BRIEF DESCRIPTION OF THE FIGURE

Figure 1 illustrates the effects of endotoxin (LPS-4 mg/kg) treatment on mean arterial pressure (MAP) with and without  $[(\text{MGD})_2/\text{Fe}]$  treatment. Bolus i.v. injection of LPS at time zero was as indicated in the Figure. Data marked by open circles [O] are the result of bolus i.v. injection of 1.0 ml saline, followed by 1.0 ml/hr of continuous saline infusion (n=11/16, note: 11 out of 16 animals died before the end of the experiments). Data marked by closed circles [ $\bullet$ ], are the result of  $[(\text{MGD})_2/\text{Fe}]$  infusion, 0.1 mmole/kg loading dose followed by 0.1 mmole/kg/hr i.v. infusion (n=3/16, note: only 3 out of 16 animals died before the end of the experiments). Data points marked with an asterisk (\*) indicate the results are significantly different at  $p < 0.05$ . The ratio of MGD to Fe used was 5:1 (MGD:Fe), and the dosage shown was with respect to MGD.

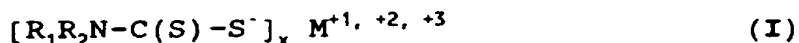
#### DETAILED DESCRIPTION OF THE INVENTION

In accordance with the present invention, there are provided combinational therapeutic methods for treating a variety of conditions related to the overproduction of nitric oxide by a subject. In one aspect, the invention method comprises directly or indirectly treating the production of species which induce the expression of inducible nitric oxide synthase in a subject. Invention methods comprise:

co-administering to a subject an effective amount  
of a combination of at least one agent  
capable of directly or indirectly  
inactivating said species, or inhibiting  
production of said species, and at least one  
dithiocarbamate-containing nitric oxide  
scavenger.

In accordance with another aspect of the present  
invention, combinational therapeutic methods have been  
developed employing an effective amount of a combination of  
at least one treating agent useful for the treatment of  
infectious and/or inflammatory conditions, and at least one  
dithiocarbamate-containing nitric oxide scavenger. It has  
been found that the above-described combination is more  
effective for the treatment of infectious and/or  
inflammatory conditions than is the treating agent alone.

Dithiocarbamate-containing nitric oxide  
scavengers contemplated for use in the practice of the  
present invention include any physiologically compatible  
derivative of the dithiocarbamate moiety (i.e.,  
(R)<sub>2</sub>N-C(S)-SH). Such compounds can be described with  
reference to the following generic structure (I):



wherein:

each R<sub>1</sub> and R<sub>2</sub> is independently selected from a C<sub>1</sub>  
up to C<sub>18</sub> alkyl, substituted alkyl,  
cycloalkyl, substituted cycloalkyl,  
heterocyclic, substituted heterocyclic,  
alkenyl, substituted alkenyl, alkynyl,  
substituted alkynyl, aryl, substituted aryl,  
heteroaryl, substituted heteroaryl,  
alkylaryl, substituted alkylaryl, arylalkyl,  
substituted arylalkyl, arylalkenyl,  
substituted arylalkenyl, arylalkynyl,

substituted arylalkynyl, aroyl, substituted aroyl, acyl, substituted acyl or  $R_1$  and  $R_2$  can cooperate to form a 5-, 6- or 7-membered ring including N,  $R_1$  and  $R_2$ ,

5           x is 1 or 2, and

M is a monovalent cation when x is 1, or M is a physiologically compatible divalent or trivalent transition metal cation when x is 2.

10           Presently preferred compounds having the above-described generic structure (I) are those wherein:

each of  $R_1$  and  $R_2$  = a  $C_1$  up to  $C_{12}$  alkyl, substituted alkyl, alkenyl, substituted alkenyl, alkynyl or substituted alkynyl, wherein the substituents are selected from carboxyl,  $-C(O)H$ , oxyacyl, phenol, phenoxy, pyridinyl, pyrrolidinyl, amino, amido, hydroxy, nitro or sulfonyl, and

20           M =  $Fe^{+2}$  or  $Fe^{+3}$ .

Especially preferred compounds having the above-described generic structure are those wherein:

25            $R_1$  = a  $C_2$  up to  $C_8$  alkyl or substituted alkyl, wherein the substituents are selected from carboxyl, acetyl, pyridinyl, pyrrolidinyl, amino, amido, hydroxy or nitro,

$R_2$  is selected from a  $C_1$  up to  $C_6$  alkyl or substituted alkyl, or  $R_2$  can cooperate with  $R_1$  to form a 5-, 6- or 7-membered ring including N,  $R_2$  and  $R_1$ , and

30           M =  $Fe^{+2}$ .

The presently most preferred compounds having the above-described generic structure are those wherein:

- $R_1$  = a  $C_2$  up to  $C_8$  alkyl or substituted alkyl, wherein the substituents are selected from carboxyl, acetyl, amido or hydroxy,
- 5  $R_2$  = a  $C_1$  up to  $C_4$  alkyl or substituted alkyl, and
- $M = Fe^{+2}$ .

When  $R_1$  and  $R_2$  cooperate to form a 5-, 6- or 7-membered ring, the combination of  $R_1$  and  $R_2$  can be a variety  
10 of saturated or unsaturated 4, 5 or 6 atom bridging species selected from alkenylene or -O-, -S-, -C(O)- and/or -N(R)- containing alkylene moieties, wherein R is hydrogen or a lower alkyl moiety.

Monovalent cations contemplated for incorporation  
15 into compounds of structure (I) include  $H^+$ ,  $Na^+$ ,  $NH_4^+$ , tetraalkyl ammonium, and the like. Physiologically compatible divalent or trivalent transition metal cations contemplated for incorporation into the above compounds include charged forms of iron, cobalt, copper, manganese,  
20 or the like (e.g.,  $Fe^{+2}$ ,  $Fe^{+3}$ ,  $Co^{+2}$ ,  $Co^{+3}$ ,  $Cu^{+2}$ ,  $Mn^{+2}$  or  $Mn^{+3}$ ). In accordance with the present invention, the ratio of dithiocarbamate-species to counter-ion M can vary widely. Thus, dithiocarbamate-containing nitric oxide scavenger can be administered without any added metallic counter-ion  
25 (i.e.,  $M = H^+$ , or a transition metal cation to dithiocarbamate-species ratio of zero), with ratios of transition metal cation to dithiocarbamate-species up to about 1:2 (i.e., a 2:1 dithiocarbamate:transition metal cation complex) being suitable.

30 As employed herein, "substituted alkyl" comprises alkyl groups further bearing one or more substituents selected from hydroxy, alkoxy (of a lower alkyl group; wherein a lower alkyl group has about 1-4 carbon atoms), mercapto (of a lower alkyl group), cycloalkyl, substituted

cycloalkyl, heterocyclic, substituted heterocyclic, aryl, substituted aryl, heteroaryl, substituted heteroaryl, aryloxy, substituted aryloxy, halogen, trifluoromethyl, cyano, nitro, nitron, amino, amido, -C(O)H, acyl, oxyacyl, 5 carboxyl, carbamate, sulfonyl, sulfonamide, sulfuryl, and the like.

As employed herein, "cycloalkyl" refers to cyclic ring-containing groups containing in the range of about 3 up to 8 carbon atoms, and "substituted cycloalkyl" refers 10 to cycloalkyl groups further bearing one or more substituents as set forth above.

As employed herein, "alkenyl" refers to straight or branched chain hydrocarbyl groups having at least one carbon-carbon double bond, and having in the range of about 15 2 up to 12 carbon atoms, and "substituted alkenyl" refers to alkenyl groups further bearing one or more substituents as set forth above.

As employed herein, "alkynyl" refers to straight or branched chain hydrocarbyl groups having at least one 20 carbon-carbon triple bond, and having in the range of about 2 up to 12 carbon atoms, and "substituted alkynyl" refers to alkynyl groups further bearing one or more substituents as set forth above.

As employed herein, "aryl" refers to aromatic 25 groups having in the range of 6 up to 14 carbon atoms and "substituted aryl" refers to aryl groups further bearing one or more substituents as set forth above.

As employed herein, "alkylaryl" refers to alkyl-substituted aryl groups and "substituted alkylaryl" refers 30 to alkylaryl groups further bearing one or more substituents as set forth above.

As employed herein, "arylalkyl" refers to aryl-substituted alkyl groups and "substituted arylalkyl" refers to arylalkyl groups further bearing one or more substituents as set forth above.

5           As employed herein, "arylalkenyl" refers to aryl-substituted alkenyl groups and "substituted arylalkenyl" refers to arylalkenyl groups further bearing one or more substituents as set forth above.

10           As employed herein, "arylalkynyl" refers to aryl-substituted alkynyl groups and "substituted arylalkynyl" refers to arylalkynyl groups further bearing one or more substituents as set forth above.

15           As employed herein, "aroyl" refers to aryl-carbonyl species such as benzoyl and "substituted aroyl" refers to aroyl groups further bearing one or more substituents as set forth above.

20           As employed herein, "heterocyclic" refers to cyclic (i.e., ring-containing) groups containing one or more heteroatoms (e.g., N, O, S, or the like) as part of the ring structure, and having in the range of 3 up to 14 carbon atoms and "substituted heterocyclic" refers to heterocyclic groups further bearing one or more substituents as set forth above.

25           As employed herein, "acyl" refers to alkyl-carbonyl species.

As employed herein, "halogen" refers to fluoride, chloride, bromide or iodide atoms.

Induction of expression of inducible nitric oxide synthase, and hence, overproduction of nitric oxide, is  
30 associated with a wide range of disease states and/or

indications, such as, for example, septic shock, ischemia, administration of cytokines, overexpression of cytokines, ulcers, inflammatory bowel disease (e.g., ulcerative colitis or Crohn's disease), diabetes, arthritis, asthma, 5 Alzheimer's disease, Parkinson's disease, multiple sclerosis, cirrhosis, allograft rejection, encephalomyelitis, meningitis, pancreatitis, peritonitis, vasculitis, lymphocytic choriomeningitis, glomerulonephritis, uveitis, ileitis, liver inflammation, 10 renal inflammation, hemorrhagic shock, anaphylactic shock, burn, infection (including bacterial, viral, fungal and parasitic infections), hemodialysis, chronic fatigue syndrome, stroke, cancers (e.g., breast, melanoma, carcinoma, and the like), cardiopulmonary bypass, 15 ischemic/reperfusion injury, and the like.

Treatment of such conditions can be carried out with a variety of reagents, such as, for example, anti-cytokine antibodies, anti-cytokine receptor antibodies, anti-endotoxin antibodies, bradykinin antagonists, 20 synthetic peptide blocking bradykinin receptors, bactericidal/permeability increasing protein, antibodies to platelet activating factor, inhibitors of arachidonate metabolism, inhibitors of nitric oxide synthase enzymes, immunosuppressors, diabetic therapeutic agents, 25 anti-inflammatories, agents useful for stroke therapy, agents useful for asthma therapy, agents useful for cirrhosis therapy, anti-cancer therapeutics, anti-microbial therapeutics, anti-fungal therapeutics, anti-retroviral therapeutics, agents useful for the treatment of 30 opportunistic infections and malignancies, agents useful for the treatment of Lupus erythymatosus, agents useful for the treatment of uveitis, thrombolytic agents, antispasmodic agents, antidiarrheal agents, agents useful for the treatment of constipation, antihistamines, agents 35 useful for the treatment of Parkinson's disease, and the like. Such agents, employed either alone or as part of a



combination of any two or more thereof, can advantageously be combined with dithiocarbamate-containing nitric oxide scavengers as described herein, and can be used for a variety of indications, such as for example,

- 5           anti-endotoxin therapy (e.g., antibodies to endotoxin, antibodies to LPS-binding protein, soluble CD14 protein, bactericidal/permeability increasing protein, polymyxin B, and the like),
- 10          inhibition of cytokine synthesis/release (e.g., employing phosphodiesterase inhibitors, IL-4, IL-10, IL-13, TGF- $\beta$ , corticosteroids, and the like),
- 15          anti-cytokine therapy (e.g., employing antibodies to TNF, soluble TNF receptors, IL-1 receptor antagonists, antibodies to IL-1 receptors, antibodies to IL-6, antibodies to interferon- $\gamma$ , soluble interferon- $\gamma$  receptors, and the like),
- 20          inhibition of the coagulation cascade (and of complement activation, employing such agents as anti-Factor XII antibodies, antibodies to C5a, C1-esterase inhibitors, soluble Crl, and the like),
- 25          inhibition of platelet activating factor (PAF, employing such agents as PAF receptor antagonists, and the like),
- 30          inhibition of arachidonate metabolism (e.g., employing agents such as cyclooxygenase inhibitors, lipoxxygenase inhibitors, leukotriene inhibitors, thromboxane A<sub>2</sub> inhibitors, prostaglandins, and the like),
- 35          inhibition of nitric oxide synthase enzymes (e.g., employing arginine analogs (such as L-N<sup>G</sup>-methylarginine, L-N<sup>G</sup>-nitroarginine, L-N<sup>G</sup>-aminoarginine, L-iminoethylornithine,  $\epsilon$ -N-iminoethyl-L-lysine, L-N<sup>G</sup>-nitroarginine

5 methyl ester, L-N<sup>G</sup>-hydroxyl-N<sup>G</sup>-methylarginine, L-N<sup>G</sup>-methyl-N<sup>G</sup>-methylarginine, L-thiocitrulline, L-S-methylthiocitrulline, L-S-ethylisothiocitrulline, S-ethylisothiocitrulline, aminoguanidine, S-methyl isothiourrea sulfate, and the like),  
10 heme ligands (such as 7-nitroindazole, 7,7,8,8-tetramethyl-o-quinodimethane, imidazole, 1-phenylimidazole, 2-phenylimidazole, and the like), calmodulin antagonists (such as chlorpromazine, W-7, and the like);

15 immunosuppression (e.g., employing one or more agents such as cyclosporin A, OKT3, FK506, mycophenolate mofetil (MMF), azathioprine, corticosteroids (such as prednisone), antilymphocyte globulin, antithymocyte globulin, and the like),

20 diabetic therapy (e.g., employing one or more agents such as free pancreatic islets, encapsulated pancreatic islets, oral insulin, intravenous insulin, amylin hormone, and the like), dihydropyridine  
25 calcium channel blockers (e.g., employing agents such as nifedipine, nitrendipine, nisoldipine, and the like), acetohexamide, chlorpropamide, glyburide, glipizide, metformin, tolbutamide, tolazamide, and the  
30 like,

inflammatory disease therapy (e.g., employing  
35 disease-modifying agents (such as antimalarials, methotrexate, sulfasalazine, mesalamine, azathioprine, 6-mercaptopurine, metronidazole, injectable and oral gold, D-penicillamine, and the like), corticosteroids, non-steroidal

5 antiinflammatory drugs (such as acetaminophen, aspirin, sodium salicylate, magnesium salicylate, choline magnesium salicylate, salicylsalicylic acid, ibuprofen, naproxen, diclofenac, diflunisal, etodolac, fenoprofen calcium, fluriprofen, piroxicam, indomethacin, ketoprofen, ketorolac tromethamine, meclofenamate, meclofenamate sodium, mefenamic acid, 10 nabumetone, oxaprozin, phenyl butyl nitron (PBN), sulindac, tolmetin, and the like), and the like),

stroke therapy (e.g., employing one or more agents such as fibrinolytic agents (such as 15 streptokinase, acylated plasminogen-streptokinase complex, urokinase, tissue plasminogen activator, and the like), employing monoclonal antibodies directed against leukocyte adhesion molecules (such as 20 intercellular adhesion molecule-1 (ICAM-1), CD18, and the like), hemodilution therapy (employing modified hemoglobin solutions such as diaspirin crosslinked hemoglobin), employing growth factors (such as 25 basic fibroblast growth factor (bFGF), transforming growth factor-beta 1 (TGF- $\beta$ 1), and the like), employing glutamate antagonists (such as lamotrigine, dizolcilpine maleate (MK 801), BW619C89, BW1003C87, and the like), employing NMDA 30 antagonists (such as CGS 19755 (Selfotel), aptiganel hydrochloride, dextrorphan, d-CPPene, and the like), employing GABA agonists (such as muscimol), employing free radical scavengers (such as allopurinol, S-PBN, 21-aminosteroids, tocopherol, superoxide dismutase, dexamethasone (HU-211), 35

selenium, carotenoids, and the like),  
idebenone, ticlopidine, lovastatin,  
citicoline, and the like),  
asthma therapy (e.g., employing bronchodilators  
5 (such as albuterol, salmeterol,  
metaproternol, bitolterol, pirbuterol,  
terbutaline, isoproterenol, epinephrine, and  
the like), theophyllines (such as  
theophylline, aminophylline, and the like),  
10 corticosteroids (such as beclomethasone,  
prednisone, and the like), antimediators  
(such as cromolyn sodium, nedocromil sodium,  
and the like), and the like),  
cirrhosis therapy (e.g., employing diuretics  
15 (such as spironolactone), opiate antagonists  
(such as naloxone), cholestyramine,  
colchicine, colestipol, methotrexate,  
rifampin, ursodeoxycholic acid, and the  
like,  
20 anti-cancer therapy (e.g., employing one or more  
agents such as alkylating agents (such as  
mechlorethamine, chlorambuccil, ifosfamide,  
melphalan, busulfan, carmustine, lomustine,  
procarbazine, dacarbazine, cisplatin,  
25 carboplatin, and the like), antimetabolites  
(such as methotrexate, mercaptopurine,  
thioguanine fluorouracil, cytarabine, and  
the like), hormonal agents (such as  
testosterone propionate, fluoxymesterone,  
30 flutamide, diethylstilbestrol, ethinyl  
estradiol, tamoxifen, hydroxyprogesterone  
caproate, medroxyprogesterone, megestrol  
acetate, and the like),  
adrenocorticosteroids (such as prednisone),  
35 aromatase inhibitors (such as amino  
glutethimide), leuprolide, goserelin  
acetate, biological response modifiers (such

as interferon- $\alpha$ 2a, interferon- $\alpha$ 2b, interleukin-2, and the like), peptide hormone inhibitors (such as octreotide acetate), natural products (such as

5 vinblastine, vincristine, vinorelbine, paclitaxel, dactinomycin, daunorubicin, idarubicin, doxorubicin, etoposide, plicamycin, mitomycin, mitoxantrone, bleomycin, hydroxyurea, mitotane,

10 fludarabine, cladribine, and the like), supportive agents (such as allopurinol, mesna, leucovorin, erythropoietin, filgrastim, sargramostim, and the like), and the like,

15 anti-microbial therapy (e.g., employing one or more agents such as ceftriaxone, TMP-SMZ, penicillin, aminoglycosides, vancomycin, gentamicin, rifampin, imipenem, clindamycin, metronidazole, tetracycline, erythromycin, sulfonamide, streptomycin, ampicillin,

20 isoniazid, pyrazinamide, ethambutol, and the like),

anti-fungal therapy (e.g., employing agents such as amphotericin B, griseofulvin, myastatin,

25 flucytosine, natamycin, antifungal imidazoles (e.g., clotrimazole, miconazole, ketoconazole, fluconazole, itraconazole, and the like), and the like,

anti-retroviral therapy (e.g., employing agents

30 such as protease inhibitors (such as Invirase, Ritonavir, Crixivan, and the like), zidovudine, didanosine, zalcitabine, stavudine, viramune, and the like)

treatment of opportunistic infections and

35 malignancies (e.g., anti-AIDS treatment, employing agents such as pentamidine, trimethoprim/sulfamethoxazole, primaquine,

atovaquone, clarithromycin, clofazimine,  
ethambutol, rifampin, amikacin,  
ciprofloxacin, pyrimethamine, amphotericin  
B, ganciclovir, foscarnet, fluconazole,  
5 ketoconazole, acyclovir, and the like),  
Lupus erythymatosus therapy (e.g., employing  
agents such as hydroxychloroquine sulfate,  
chloroquine sulfate, quinacrine, dapsone,  
isotretinoin, and the like),  
10 uveitis therapy (e.g., employing agents such as  
corticosteroids, azathioprine, cyclosporine,  
and the like),  
thrombolytic therapy for acute myocardial  
infarction (e.g., employing agents such as  
15 streptokinase, tissue plasminogen activator  
(t-PA), anistreplase, and the like),  
antispasmodic treatment (e.g., employing agents  
such as dicyclomine, hyoscyamine,  
propantheline, and the like),  
20 antidiarrheal treatment (e.g., employing agents  
such as loperamide, diphenoxylate with  
atropine, and the like),  
anticonstipation treatment (e.g., employing  
agents such as fiber supplementation with  
25 bran, psyllium, methylcellulose,  
polycarbophil, cisapride, and the like),  
antihistamine therapy (e.g., employing agents  
such as ethanolamines (such as  
diphenhydramine, clemastine, and the like),  
30 ethylenediamines (such as brompheniramine,  
chlorpheniramine, triprolidine, and the  
like), phenothiazines (such as hydroxyzine),  
piperidines (such as terfenadine,  
astemizole, azatadine, cyproheptadiene,  
35 loratidine, and the like), and the like),  
anti-Parkinsonian therapy (e.g., employing agents  
such as benztropine mesylate, biperiden,

chlorphenoxamine, cycrimine, orphenadrine, procyclidine, trihexyphenidyl, and the like),

as well as other indications which involve the induction of  
5 nitric oxide synthase, as can readily be identified by those of skill in the art.

Presently preferred indications for treatment in accordance with the present invention include septic shock, ischemia, ulcers, ulcerative colitis, diabetes, arthritis,  
10 asthma, Alzheimer's disease, Parkinson's disease, multiple sclerosis, cirrhosis or allograft rejection, and the like.

In accordance with a particular aspect of the present invention, the dithiocarbamate-containing nitric oxide scavenger is administered in combination with one or  
15 more of the above-described agents, optionally including an antibiotic (e.g., gentamicin, tobramycin, amikacin, piperacillin, clindamycin, cefoxitin or vancomycin, or mixtures thereof), a vasoactive agent (e.g., a catecholamine, noradrenaline, dopamine or dobutamine), or  
20 mixtures thereof. In this way, the detrimental side effects of many of the above-noted pharmaceutical agents or the indication they are designed to address (e.g., systemic hypotension) can be prevented or reduced by co-administration of a combination reagent including a  
25 dithiocarbamate-containing nitric oxide scavenger.

Those of skill in the art recognize that the combination of an agent capable of inactivating species which induce the expression of inducible nitric oxide (or an agent capable of inhibiting the production of such  
30 species), and dithiocarbamate-containing nitric oxide scavengers described herein can be delivered in a variety of ways, such as, for example, orally, intravenously, subcutaneously, parenterally, rectally, by inhalation, and the like.

Since individual subjects may present a wide variation in severity of symptoms and each drug has its unique therapeutic characteristics, the precise mode of administration, dosage employed and treatment protocol for  
5 each subject is left to the discretion of the practitioner.

In accordance with still another embodiment of the present invention, there are provided physiologically active composition(s) comprising an "agent" and a compound having the structure I, as described above, in a suitable  
10 vehicle rendering said compound amenable to oral delivery, transdermal delivery, intravenous delivery, intramuscular delivery, topical delivery, nasal delivery, and the like.

Depending on the mode of delivery employed, the above-described compositions can be delivered in a variety  
15 of pharmaceutically acceptable forms. For example, the above-described compositions can be delivered in the form of a solid, solution, emulsion, dispersion, micelle, liposome, and the like.

Pharmaceutical compositions of the present  
20 invention can be used in the form of a solid, a solution, an emulsion, a dispersion, a micelle, a liposome, and the like, wherein the resulting composition contains one or more each of the scavenging and inhibiting compounds contemplated for use in the practice of the present  
25 invention, as active ingredients thereof, in admixture with an organic or inorganic carrier or excipient suitable for enteral or parenteral applications. The active ingredients may be compounded, for example, with the usual non-toxic, pharmaceutically acceptable carriers for tablets, pellets,  
30 capsules, suppositories, solutions, emulsions, suspensions, and any other form suitable for use. The carriers which can be used include glucose, lactose, gum acacia, gelatin, mannitol, starch paste, magnesium trisilicate, talc, corn starch, keratin, colloidal silica, potato starch, urea,



medium chain length triglycerides, dextrans, and other carriers suitable for use in manufacturing preparations, in solid, semisolid, or liquid form. In addition auxiliary, stabilizing, thickening and coloring agents and perfumes  
5 may be used. The active compounds (i.e., "agents" and compounds of structure I as described herein) are included in the pharmaceutical composition in an amount sufficient to produce the desired effect upon the target process, condition or disease.

10                   Pharmaceutical compositions containing the active ingredients contemplated herein may be in a form suitable for oral use, for example, as tablets, troches, lozenges, aqueous or oily suspensions, dispersible powders or granules, emulsions, hard or soft capsules, or syrups or  
15 elixirs. Compositions intended for oral use may be prepared according to any method known in the art for the manufacture of pharmaceutical compositions. In addition, such compositions may contain one or more agents selected from a sweetening agent (such as sucrose, lactose, or  
20 saccharin), flavoring agents (such as peppermint, oil of wintergreen or cherry), coloring agents and preserving agents, and the like, in order to provide pharmaceutically elegant and palatable preparations. Tablets containing the active ingredients in admixture with non-toxic  
25 pharmaceutically acceptable excipients may also be manufactured by known methods. The excipients used may be, for example, (1) inert diluents such as calcium carbonate, lactose, calcium phosphate, sodium phosphate, and the like; (2) granulating and disintegrating agents such as corn  
30 starch, potato starch, alginic acid, and the like; (3) binding agents such as gum tragacanth, corn starch, gelatin, acacia, and the like; and (4) lubricating agents such as magnesium stearate, stearic acid, talc, and the like. The tablets may be uncoated or they may be coated by  
35 known techniques to delay disintegration and absorption in the gastrointestinal tract, thereby providing sustained

action over a longer period. For example, a time delay material such as glyceryl monostearate or glyceryl distearate may be employed. They may also be coated by the techniques described in the U.S. Pat. Nos. 4,256,108; 4,160,452; and 4,265,874, to form osmotic therapeutic tablets for controlled release.

In some cases, formulations for oral use may be in the form of hard gelatin capsules wherein the active ingredients are mixed with an inert solid diluent, for example, calcium carbonate, calcium phosphate, kaolin, or the like. They may also be in the form of soft gelatin capsules wherein the active ingredients are mixed with water or an oil medium, for example, peanut oil, liquid paraffin, or olive oil.

The pharmaceutical compositions may be in the form of a sterile injectable suspension. This suspension may be formulated according to known methods using suitable dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally-acceptable diluent or solvent, for example, as a solution in 1,3-butanediol. Sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose any bland fixed oil may be employed including synthetic mono- or diglycerides, fatty acids (including oleic acid), naturally occurring vegetable oils like sesame oil, coconut oil, peanut oil, cottonseed oil, etc., or synthetic fatty vehicles like ethyl oleate or the like. Buffers, preservatives, antioxidants, and the like can be incorporated as required.

Compositions contemplated for use in the practice of the present invention may also be administered in the form of suppositories for rectal administration of the active ingredients. These compositions may be prepared by

mixing the active ingredients with a suitable non-irritating excipient, such as cocoa butter, synthetic glyceride esters of polyethylene glycols (which are solid at ordinary temperatures, but liquify and/or dissolve in the rectal cavity to release the active ingredients), and the like.

Since individual subjects may present a wide variation in severity of symptoms and each active ingredient has its unique therapeutic characteristics, it is up to the practitioner to determine a subject's response to treatment and vary the dosages accordingly.

Typical daily doses of dithiocarbamate-containing nitric oxide scavengers, in general, lie within the range of from about 10  $\mu$ g up to about 100 mg per kg body weight, and, preferably within the range of from 50  $\mu$ g to 10 mg per kg body weight and can be administered up to four times daily. The daily IV dose lies within the range of from about 1  $\mu$ g to about 100 mg per kg body weight, and, preferably, within the range of from 10  $\mu$ g to 10 mg per kg body weight.

In general, the dosage of dithiocarbamate-containing nitric oxide scavenger employed in the practice of the present invention falls in the range of about 0.01 mmoles/kg body weight of the subject/hour up to about 0.5 mmoles/kg/hr.

The invention will now be described in greater detail by reference to the following non-limiting examples.

#### Example 1

Wistar rats (male, 230-300 g) were supplied by Simonson Laboratories (Gilroy, CA).

Lipopolysaccharide (LPS; *S. typhosa*, endotoxin) was obtained from Sigma (St. Louis, MO).

*N*-Methyl-D-glucamine and carbon disulfide were obtained from Aldrich (Milwaukee, WI). *N*-Methyl-D-glucamine dithiocarbamate (MGD) was synthesized by following the method of Shinobu et al. (Acta Pharmacol. Toxicol. 54:189-194 (1984)).

### Example 2

As described previously (see Lai and Komarov in FEBS Lett. 345:120-124 (1994)), one [(MGD)<sub>2</sub>/Fe] complex binds to one molecule of nitric oxide to form a [(MGD)<sub>2</sub>/Fe-NO] complex. Whereas free nitric oxide is a potent vasodilator, nitric oxide bound to [(MGD)<sub>2</sub>/Fe] is not. The resulting complex is then excreted from the body in the urine, thereby reducing in vivo nitric oxide levels.

The effects of [(MGD)<sub>2</sub>/Fe] treatment on the mean arterial pressure of endotoxemia in rats are shown in Figure 1. When rats were treated with lethal doses of LPS, the mean arterial pressure dropped gradually with time and reached 75 mm Hg at the end of 2 hours. In controls, when the animals were infused with saline, their mean arterial pressure remained very low; indeed, 11 out of 16 animals died before the end of the experiments. On the other hand, when the LPS-treated animals were infused with [(MGD)<sub>2</sub>/Fe], their mean arterial pressure gradually restored to normal levels, and only 3 out of 16 animals died before the end of the experiments. Therefore, infusions of [(MGD)<sub>2</sub>/Fe] can not only restore blood pressure, but also reduces the mortality rate in endotoxin induced septic shock rats.

In summary, [(MGD)<sub>2</sub>/Fe] is potentially useful for the treatment of systemic hypotension (extreme drop in blood pressure), caused by abnormally elevated levels of

nitric oxide; a condition which has been associated with many inflammatory and infectious diseases. In addition, [(MGD)<sub>2</sub>/Fe] has been shown to be safe inasmuch as the animals survived after injections of up to 1% of their body weight without apparent side effects (Lai and Komarov, supra).

### Example 3

As previously described (see Komarov and Lai in Biochim. Biophys. Acta 1272:29-36 (1995)), subcutaneous administration of the [(MGD)<sub>2</sub>/Fe] complex reduced in vivo NO levels in LPS-treated mice. Since excessive NO production is known to induce systemic hypotension, injections of the [(MGD)<sub>2</sub>/Fe] complex that reduce in vivo NO levels should also restore blood pressure in hypotensive animals induced by LPS treatment. To test this idea, experiments were carried out to determine the effects of administration of the [(MGD)<sub>2</sub>/Fe] complex on the blood pressure of the hypotensive rats induced by LPS challenge.

Thus, male Wistar rats (230-300 g) fasted overnight were anesthetized with thiobutabarbital (Inactin, 100 mg/kg, i.p.). A catheter was implanted in the femoral vein for drug infusions. The femoral artery was cannulated for continuous blood pressure measurement. Rats were injected with an i.v. bolus dose of LPS (S.Typhosa endotoxin, 4 mg/kg). Two hours after LPS challenge, rats were then subjected to one of the following treatments:

- (a) Control, saline infusion- 1.0 ml saline i.v. injection followed by 1.0 ml/hr of saline infusion for 2.0 hours,
- (b) [(MGD)<sub>2</sub>/Fe] (at a ratio of 2-to-0.4)-0.1 mmole/kg i.v. bolus injection followed by 0.1 mmole/kg infusion for 2.0 hours,

- (c)  $[(\text{MGD})_2/\text{Fe}]$  (at a ratio of 2-to-0.2)-0.1 mmole/kg i.v. bolus injection followed by 0.1 mmole/kg infusion for 2.0 hours, and
- (d)  $[(\text{MGD})_2/\text{Fe}]$  (at a ratio of 2-to-0)-0.1 mmole/kg i.v. bolus injection followed by 0.1 mmole/kg infusion for 2.0 hours.

The results of mean arterial pressure (MAP) measurement as a result of each of these treatments are summarized in Table 1.

10

Table 1

Effects of various ratios of  $[(\text{MGD})_2/\text{Fe}]$  treatment on the mean arterial pressure (MAP in mmHg) in lipopolysaccharide (LPS)-induced shock rats

Conditions <sup>1</sup>	Baseline <sup>2</sup> (mean $\pm$ SEM)	2 hrs after LPS Exposure	2.0 hrs after Treatment
a) Control saline (n=16) <sup>3</sup>	96 $\pm$ 2	77 $\pm$ 2	76 $\pm$ 7
b) $[(\text{MGD})_2/\text{Fe}]$ (2/0.4) <sup>4</sup> (n=16)	95 $\pm$ 3	75 $\pm$ 2	95 $\pm$ 3
c) $[(\text{MGD})_2/\text{Fe}]$ (2/0.2) (n=9)	98 $\pm$ 2	75 $\pm$ 3	89 $\pm$ 4
d) MGD (2/0) (n=9)	99 $\pm$ 4	71 $\pm$ 2	94 $\pm$ 6

- <sup>1</sup> Experimental conditions were as described in the text.  
<sup>2</sup> The values of MAP prior to LPS treatment.  
<sup>3</sup> n, the number of animals in each group.  
<sup>4</sup>  $[(\text{MGD})_2/\text{Fe}]$  (2/0.4) is defined as the ratio of  $[(\text{MGD})_2/\text{Fe}]$  to be 2-to-0.4.

The MAP of anesthetized rats was in the range of 96 to 99 mmHg. Two hours after LPS treatment, the MAP decreased to between 71 and 77 mmHg, which is indicative of the onset of systemic hypotension, caused by abnormally

elevated levels of nitric oxide, as also shown in Figure 1. While the 2.0 hr saline infusion did not change the MAP, infusions of [(MGD)<sub>2</sub>/Fe] complex at various ratios, ranging from 2-to-0.4 (MGD to Fe) to 2-to-0 (MGD to Fe), restored  
5 the blood pressure to 89-95 mmHg (Table 1). These results suggest that the i.v. infusion of MGD either with or without added iron (Fe), can restore blood pressure in hypotensive rats induced by LPS challenge (Table 1).

Since MGD does not bind ·NO, it is speculated  
10 that the restoration of the MAP by MGD infusion may be attributed to the MGD chelation of cellular iron released by excess ·NO production, which is known to attack cellular iron-containing proteins and result in cellular iron loss during sepsis or septic shock (see, for example, Kim et  
15 al., in J. Biol. Chem. 270:5710-5713 (1995)).

This example shows that dithiocarbamate-containing nitric oxide scavengers, such as MGD, either with or without added iron, are effective for the treatment of systemic hypotension, a condition which is associated  
20 with many inflammatory and/or infectious diseases.

#### Example 4

In order to test the efficacy of the combinational therapy of [(MGD)<sub>2</sub>/Fe] and anti-TNF antibody for treatment of LPS-induced shock, Wistar rats are  
25 anesthetized with Ketamine/Xylazine (55 mg/kg plus 5.5 mg/kg). A catheter is implanted in the femoral vein for drug administration. The femoral artery is cannulated for continuous blood pressure measurement. The animals are allowed to recover from surgery for a period of 3 days  
30 prior to experimentation. On the day of the experiment, the conscious rats are retained in restrainers and the artery line is connected to the pressure transducer for recording. Rats are injected with an i.v. bolus dose of

LPS (*S. Typhosa*, endotoxin, 10-20 mg/kg). Two hours after LPS challenge, rats are then subjected to one of the following treatments (8 animals in each group):

- 5 (1) Control, saline infusion - 1.0 ml saline/hr of saline infusion for 6 hours.
- (2)  $[(\text{MGD})_2/\text{Fe}]$  (at a ratio of 5 to 1) - 0.1 mmole/kg/hr infusion for 3 hours, followed by saline infusion for 3 hours.
- 10 (3) Anti-TNF- 7.5 mg/kg/hr infusion for 3 hours, followed by saline infusion for 3 hours.
- (4) Co-infusion of  $[(\text{MGD})_2/\text{Fe}]$  (0.1 mmole/kg/hr) and Anti-TNF (7.5 mg/kg/hr) for 3 hours, followed by saline infusion for 3 hours.
- 15 (5)  $[(\text{MGD})_2/\text{Fe}]$  (at a ratio of 5-to-1) -0.1 mmole/kg/hr infusion for 3 hours and followed by anti-TNF (7.5 mg/kg/hr) infusion for 3 hours.

At the end of the infusion, rats are returned to their cages for observation. The 24-hr survival rates  
20 resulting from these various treatments are compared. Since a lethal dose of LPS is used, it is expected that all animals in control group 1 will die within 24 hours. Based on the results presented in Figure 1 (Example 2), it is  
25 expected that about two thirds of the rats in the treatment group (i.e., group 2, treated with  $[(\text{MGD})_2/\text{Fe}]$ ) will survive after 24 hours. As discussed above, in endotoxemia, TNF production is short-lived and peaks at 1-2 hours. Therefore, the infusion of anti-TNF antibodies at two hours after LPS challenge as indicated in group 3 may not be able  
30 to block the induction of the inducible nitric oxide synthase gene, which results in the production of iNOS, resulting in the overproduction of nitric oxide. In group 4, the co-infusion of anti-TNF antibodies and  $[(\text{MGD})_2/\text{Fe}]$  is expected to produce a similar survival rate as that for  
35 group 2, employing  $[(\text{MGD})_2/\text{Fe}]$  infusion alone. On the other



hand, it is expected that the infusion of [(MGD)<sub>2</sub>/Fe] for 3 hours, followed by the infusion of anti-TNF antibodies (as done with group 5) will improve the survival rate over that in group 2, because the infusion of anti-TNF antibodies at  
5 later hours would inhibit further activation of the inducible NO synthase gene, thereby reducing the further enhancement of excessive NO production.

The efficacies of combinational therapy between [(MGD)<sub>2</sub>/Fe] and other therapeutic agents (such as anti-  
10 endotoxin antibodies, other anti-cytokine antibodies, anti-cytokine receptor antibodies, and other agents, such as antibradykinin peptides, nitric oxide synthase inhibitors, and the like) can be demonstrated in a similar fashion to that described herein.

15 While the invention has been described in detail with reference to certain preferred embodiments thereof, it will be understood that modifications and variations are within the spirit and scope of that which is described and claimed.

That which is claimed is:

1. A method for directly or indirectly treating the production of species which induce the expression of inducible nitric oxide synthase in a subject, said method comprising:

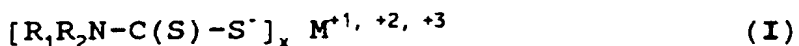
5 co-administering to said subject an effective amount of a combination of at least one agent capable of directly or indirectly inactivating said species, or inhibiting  
10 production of said species, and at least one dithiocarbamate-containing nitric oxide scavenger.

2. A method according to claim 1 wherein said species is selected from cytokines, cytokine receptors, endotoxins, platelet activating factor, bradykinin, bradykinin receptor, bacteria, coagulation factors,  
5 arachidonate metabolites or nitric oxide synthase.

3. A method according to claim 1 wherein said agent is selected from anti-endotoxin agents, inhibitors of cytokine synthesis/release, anti-cytokine agents, inhibitors of the coagulation cascade, inhibitors of  
5 complement activation, inhibitors of platelet activating factor, inhibitors of arachidonate metabolism, inhibitors of nitric oxide synthase enzymes, immunosuppressive agents, diabetic therapeutic agents, therapeutic agents for inflammatory diseases or therapeutic agents for Crohn's  
10 disease therapy.

4. A method according to claim 1 wherein said agent is selected from anti-endotoxin agents, anti-cytokine agents, inhibitors of nitric oxide synthase enzymes, immunosuppressive agents or therapeutic agents for  
5 inflammatory diseases.

5. A method according to claim 1 wherein said dithiocarbamate-containing nitric oxide scavenger comprises a dithiocarbamate moiety having the structure (I), optionally associated with a physiologically compatible di- or tri-valent transition metal ion, wherein structure (I) is as follows:



wherein:

each of  $R_1$  and  $R_2$  is independently selected from a  $C_1$  up to  $C_{18}$  alkyl, substituted alkyl, cycloalkyl, substituted cycloalkyl, heterocyclic, substituted heterocyclic, alkenyl, substituted alkenyl, alkynyl, substituted alkynyl, aryl, substituted aryl, heteroaryl, substituted heteroaryl, alkylaryl, substituted alkylaryl, arylalkyl, substituted arylalkyl, or  $R_1$  and  $R_2$  can cooperate to form a 5-, 6- or 7-membered ring including N,  $R_1$  and  $R_2$ ,  
 $x$  is 1 or 2, and  
 $M$  is a monovalent cation when  $x$  is 1, or  $M$  is a physiologically compatible divalent or trivalent transition metal cation when  $x$  is 2.

6. A method according to claim 5 wherein the ratio of transition metal ion to dithiocarbamate moiety falls in the range of zero up to about 1:2.

7. A method according to claim 5 wherein said physiologically compatible di- or tri-valent transition metal is selected from iron, cobalt, copper or manganese.

8. A method according to claim 1 wherein said combination of at least one agent, and at least one dithiocarbamate-containing nitric oxide scavenger is

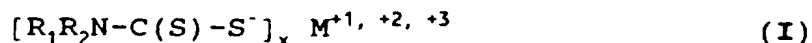
delivered orally, intravenously, subcutaneously,  
5 parenterally, rectally or by inhalation.

9. A method according to claim 1 wherein said combination of at least one agent, and at least one dithiocarbamate-containing nitric oxide scavenger is delivered in the form of a solid, solution, emulsion,  
5 dispersion, micelle or liposome.

10. In a therapeutic process which employs an agent to inactivate materials which, directly or indirectly, induce the expression of inducible nitric oxide synthase, the improvement comprising co-administering to a  
5 patient in need thereof a dithiocarbamate-containing nitric oxide scavenger in combination with said agent.

11. A method according to claim 10 wherein said agent is selected from anti-endotoxin agents, inhibitors of cytokine synthesis/release, anti-cytokine agents, inhibitors of the coagulation cascade, inhibitors of  
5 complement activation, inhibitors of platelet activating factor, inhibitors of arachidonate metabolism, inhibitors of nitric oxide synthase enzymes, immunosuppressive agents, diabetic therapeutic agents, therapeutic agents for inflammatory diseases or therapeutic agents for Crohn's  
10 disease therapy.

12. A composition comprising a combination of an agent capable of inactivating materials which, directly or indirectly, induce the expression of inducible nitric oxide synthase and a compound having structure (I) in a  
5 pharmaceutically acceptable carrier therefor, wherein said compound having structure (I) is as follows:



wherein:

each of  $R_1$  and  $R_2$  is independently selected from  
10 a  $C_1$  up to  $C_{18}$  alkyl, substituted alkyl,  
cycloalkyl, substituted cycloalkyl,  
heterocyclic, substituted heterocyclic,  
alkenyl, substituted alkenyl, alkynyl,  
substituted alkynyl, aryl, substituted aryl,  
15 heteroaryl, substituted heteroaryl,  
alkylaryl, substituted alkylaryl, arylalkyl,  
substituted arylalkyl or  $R_1$  and  $R_2$  can  
cooperate to form a 5-, 6- or 7-membered  
ring including N,  $R_1$  and  $R_2$ ,

20 x is 1 or 2, and

M is a monovalent cation when x is 1, or M is a  
physiologically compatible divalent or  
trivalent transition metal cation when x is  
2.

13. A composition according to claim 12 wherein  
M is selected from  $H^+$ ,  $Na^+$ ,  $NH_4^+$  or tetraalkyl ammonium.

14. A composition according to claim 12 wherein  
M is selected from  $Fe^{+2}$ ,  $Fe^{+3}$ ,  $Co^{+2}$ ,  $Co^{+3}$ ,  $Cu^{+2}$ ,  $Mn^{+2}$  or  $Mn^{+3}$ .

15. A composition according to claim 12 wherein  
the ratio of transition metal ion to dithiocarbamate moiety  
falls in the range of zero up to about 1:2.

16. A composition according to claim 12 wherein:  
each of  $R_1$  and  $R_2$  = a  $C_1$  up to  $C_{12}$  alkyl,  
substituted alkyl, alkenyl, substituted  
alkenyl, alkynyl or substituted  
5 alkynyl, wherein the substituents are  
selected from carboxyl,  $-C(O)H$ ,  
oxyacyl, phenol, phenoxy, pyridinyl,  
pyrrolidinyl, amino, amido, hydroxy,  
nitro or sulfuryl, and  
10  $M = Fe^{+2}$  or  $Fe^{+3}$ .

17. A composition according to claim 12 wherein:

$R_1$  = a  $C_2$  up to  $C_8$  alkyl or substituted alkyl, wherein said substituents are selected from carboxyl, acetyl, pyridinyl, pyrrolidinyl, amino, amido, hydroxy or nitro,

$R_2$  is selected from a  $C_1$  up to  $C_6$  alkyl or substituted alkyl, or  $R_2$  can cooperate with  $R_1$  to form a 5-, 6- or 7-membered ring including N,  $R_2$  and  $R_1$ , and

$M = Fe^{+2}$ .

18. A composition according to claim 12 wherein:

$R_1$  = a  $C_2$  up to  $C_8$  alkyl or substituted alkyl, wherein said substituents are selected from carboxyl, acetyl, amido or hydroxy,

$R_2$  = a  $C_1$  up to  $C_4$  alkyl or substituted alkyl, and

$M = Fe^{+2}$ .

19. A composition according to claim 12 wherein

said agent is selected from anti-endotoxin agents, inhibitors of cytokine synthesis/release, anti-cytokine agents, inhibitors of the coagulation cascade, inhibitors of complement activation, inhibitors of platelet activating factor, inhibitors of arachidonate metabolism, inhibitors of nitric oxide synthase enzymes, immunosuppressive agents, diabetic therapeutic agents, therapeutic agents for inflammatory diseases or therapeutic agents for Crohn's disease therapy, anti-cytokine antibodies, anti-cytokine receptor antibodies, anti-endotoxin antibodies, bradykinin antagonists, synthetic peptide blocking bradykinin receptors, bactericidal/permeability increasing protein or antibodies to platelet activating factor.

20. A composition according to claim 19 wherein said anti-endotoxin agent is selected from antibodies to endotoxin, antibodies to LPS-binding protein, soluble CD14 protein, bactericidal/permeability increasing protein or  
5 polymyxin B.

21. A composition according to claim 19 wherein said inhibitor of cytokine synthesis/release is selected from phosphodiesterase inhibitors, IL-4, IL-10, IL-13, TGF- $\beta$ , aspirin, phenyl butyl nitron or corticosteroids.

22. A composition according to claim 19 wherein said anti-cytokine agent is selected from antibodies to TNF, soluble TNF receptors, IL-1 receptor antagonists, antibodies to IL-1 receptors, antibodies to IL-6,  
5 antibodies to interferon- $\gamma$  or soluble interferon- $\gamma$  receptors.

23. A composition according to claim 19 wherein said inhibitor of the coagulation cascade is selected from anti-Factor XII antibodies, antibodies to C5a, C1-esterase inhibitors or soluble C1.

24. A composition according to claim 19 wherein said inhibitor of platelet activating factor is a PAF receptor antagonist.

25. A composition according to claim 19 wherein said inhibitor of arachidonate metabolism is selected from cyclooxygenase inhibitors, lipoxxygenase inhibitors, leukotriene inhibitors, thromboxane A<sub>2</sub> inhibitors, or  
5 prostaglandins.

26. A composition according to claim 19 wherein said inhibitor of nitric oxide synthase enzymes is selected from N-methyl-L-arginine,  $\epsilon$ -N-iminoethyl-L-lysine, aminoguanidine or S-methyl isothiurea sulfate.

27. A composition according to claim 19 wherein said immunosuppressive agent is selected from cyclosporin A, OKT3 or FK506.

28. A composition according to claim 19 wherein said diabetic therapeutic agent is selected from free pancreatic islets, encapsulated pancreatic islets, oral insulin, intravenous insulin, or amylin hormone.

29. A composition according to claim 19 wherein said therapeutic agent for inflammatory disease is selected from sulfasalazine, mesalamine, corticosteroids, azathioprine, 6-mercaptopurine, or metronidazole.

30. A composition according to claim 19 wherein said therapeutic agent for inflammatory disease is a dihydropyridine calcium channel blocker.

31. A composition according to claim 19 wherein said agent is selected from anti-endotoxin agents, inhibitors of cytokine synthesis/release, anti-cytokine agents, inhibitors of the coagulation cascade, inhibitors of complement activation, inhibitors of platelet activating factor, inhibitors of arachidonate metabolism, inhibitors of nitric oxide synthase enzymes, immunosuppressive agents, diabetic therapeutic agents, therapeutic agents for inflammatory diseases or therapeutic agents for Crohn's disease therapy, anti-cytokine antibodies, anti-cytokine receptor antibodies, anti-endotoxin antibodies, bradykinin antagonists, synthetic peptide blocking bradykinin receptors, bactericidal/permeability increasing protein or antibodies to platelet activating factor.

32. A composition according to claim 12 wherein said pharmaceutically acceptable carrier is selected from a solid, solution, emulsion, dispersion, micelle or liposome.



33. A composition according to claim 12 wherein said composition further comprises an enteric coating.

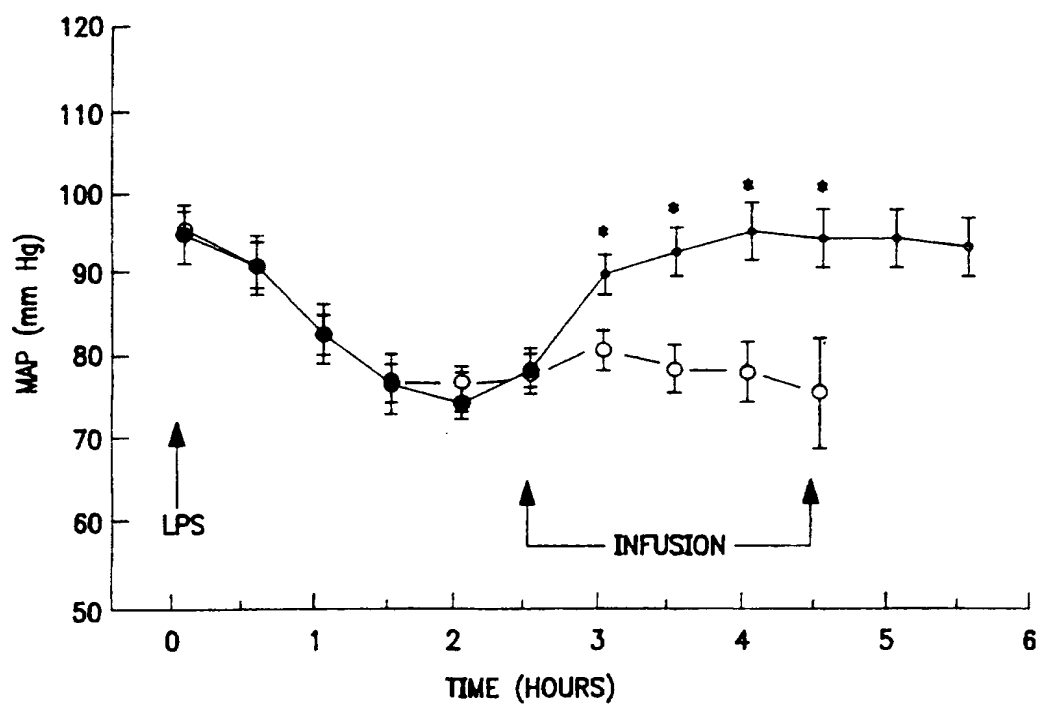


FIG. 1

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/04131**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : Please See Extra Sheet.

US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/11, 252, 291, 420, 476, 520, 634; 530/387.1, 388.4; 424/85.1; 549/39; 435/69.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

MEDLINE, WPIDS, USPATFUL

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,294,430 A (BORCH et al.) 15 March 1994, see entire document.	1-33
Y	DEGUCHI et al. Exogenous and Endogenous Type I Interferons Inhibit Interferon-Gamma-Induced Nitric Oxide Production and Nitric Oxide Synthase Expression in Murine Peritoneal Macrophages. J. Interfer. Cytokin. Res. 1995. Vol. 15, pages 977-984, see entire document.	1-33
Y	US 5,426,046 A (KAPLAN et al.) 20 June 1995, see entire document.	20
Y	US 5,449,687 A (CHRISTENSEN, IV et al.) 12 September 1995, see entire document.	21

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Z* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

21 MAY 1997

Date of mailing of the international search report

24 JUN 1997

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/04131

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,176,908 A (WISSNER et al.) 05 June 1993, see entire document.	22
Y	US 4,686,100 A (RAFFIN et al.) 11 August 1987, see entire document.	23
Y, P	US 5,530,141 A (SHEN et al.) 25 June 1996, see entire document.	24
Y	US 5,436,265 A (BLACK et al.) 25 July 1995, see entire document.	25
Y	US 5,317,040 A (GOLDMAN W.E.) 31 May 1994, see entire document.	26
Y	US 5,461,058 A (CALNE R.) 24 October 1995, see entire document.	27
Y	US 5,460,954 A (LEE et al.) 24 October 1995, see entire document.	28
Y	US 5,411,952 A (KASWAN R.) 02 May 1995, see entire document.	29
Y	US 5,137,889 A (TAMADA et al.) 11 August 1992, see entire document.	30

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/04131

A. CLASSIFICATION OF SUBJECT MATTER:

IPC (6):

A61K 31/495, 31/44, 31/50, 38/00, 45/05; A01N 43/58, 43/60, 43/42; C07K 16/00; C12P 21/08

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

514/11, 252, 291, 420, 476, 520, 634; 530/387.1, 388.4; 424/85.1; 549/39; 435/69.1

